

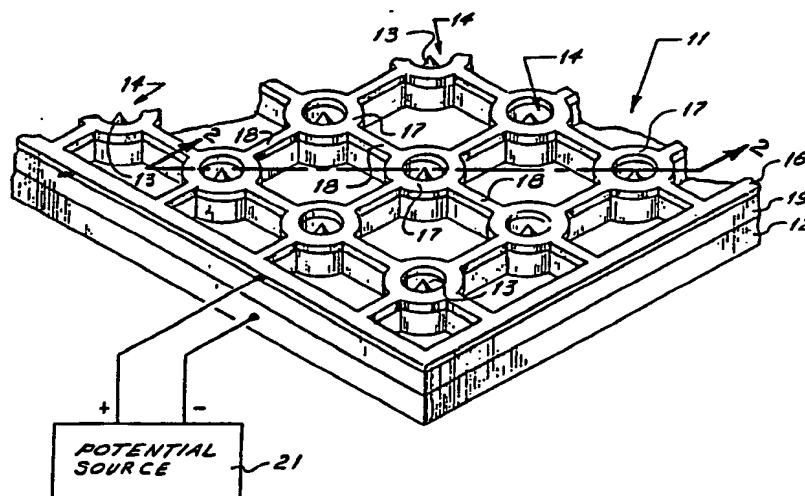


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(54) Title: AUTOMATICALLY FOCUSING FIELD EMISSION ELECTRODE**(57) Abstract**

Several embodiments of a thin film field emission cathode array are described which automatically shape the beams of emitted particles, without the addition of shaping or other electrode structure. A potential field pattern is established to control the trajectory of the emitted particles, by controlling the electromagnetic interaction of the conductive structures responsible for the particle emission.

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-1-

AUTOMATICALLY FOCUSING FIELD EMISSION ELECTRODE

DISCLOSURE

Background of the Invention

1 The present invention relates to electrically
2 charged particle emission structures. It more
3 particularly relates to a method of generating such -
4 particles and controlling their initial trajectory, to
5 a field emission structure for practicing the method,
6 and to a method of constructing the same.

7
8 Cathode structures using electrically
9 charged polarized particle emission principles now are
10 being relatively widely used and investigated as field
11 emission cathodes. Miniaturized thin film field
12 emission cathode arrays (called by many "Spindt"
13 cathodes in view of the contributions of the inventor
14 of the subject matter hereof) have attributes which
15 make them more suitable than thermal and other cold
16 cathode arrangements for many uses. For example, they
17 provide high emission current density for minimum
18 voltage operation, and most designs have a relatively
19 small geometric size in the direction of electron
20 production. Field emission cathode arrays typically
21 include an electrically conductive base structure from
22 which small needle-like electron emitting tips
23 project. A control electrode structure is spaced from
24 the base adjacent the emitting tips, and a control
25 voltage differential is established between the base
26 and the control electrode to cause the desired emission
27 of electrons from the tips. An electrical insulator

-2-

1 generally is sandwiched between the base and the
2 control electrode to prevent breakdown of the voltage
3 differential and provide mechanical support for the
4 control electrode.

5
6 The electron emitting tips are typically
7 grouped on the base at discrete locations to provide a
8 plurality of spaced-apart emissions sites, although in
9 some instances a single emitting tip is used for each
10 site. Both the control electrode and the insulator
11 have apertures at the emitting sites to enable emission
12 of electrons at such locations. U.S. Patent Nos.
13 3,665,241; 3,755,704; 3,789,471; 3,812,559; and
14 4,141,405 (all of which name the present applicant as a
15 sole or joint inventor) and the paper entitled "Recent
16 Progress in Low-Voltage Field Emission Cathode
17 Development" Journal de Physique, Supplement to Vol.
18 45, No. 12 (December 1984), provide examples of field
19 emission cathode arrays and methods of making or using
20 the same.

21
22 While field emission cathodes have many
23 desirable attributes, in the past relatively convoluted
24 and complex designs have been provided in efforts to
25 shape and direct beams of electrons, protons or ions
26 produced by the same. U.S. Patent Nos. 4,103,202;
27 4,178,531; 4,020,381; and 4,498,952 are examples of
28 such designs having added structure for these purposes.

29 30 Summary of the Invention

31
32 The present invention relates to a particle
33 field emission structure which provides initial
34 automatic shaping the beam of emitted particles,
35 without requiring added shaping or other electrode

-3-

1 structure nor design complexity. That is, it has been
2 found that by appropriately selecting the
3 electromagnetic interaction of the electrically
4 conductive structures responsible for the emission of
5 the desired particles, a potential field pattern can be
6 established by those elements which otherwise are
7 necessary for particle extraction to control the
8 trajectory of the emitted particles. In other words,
9 the desired beam shaping or other initial trajectory
10 control is automatically provided by the very same
11 elements which are responsible for the field emission,
12 without the necessity of added electrodes or other
13 structure. The potential field pattern responsible for
14 the desired trajectory could be controlled by
15 appropriate varying potential differences between such
16 elements at different spatial locations. Such control
17 also simply can be provided by appropriately selecting
18 the relationship of the physical geometries of the two
19 primary electrode structures, i.e., the base ^{or} control
20 electrode as will be described.

21
22 In preferred specific embodiments of the
23 invention, the base electrode provides a plurality of
24 particle emitting tips arranged in an array of
25 spaced-apart emission sites and has a generally
26 continuous and planer surface between the emission
27 sites, and the control electrode includes annular
28 sections circumscribing each of the sites with a linear
29 conduction section extending between adjacent sites.
30 As will become apparent from the following more
31 detailed description, this construction assures desired
32 beam shaping, is simple to manufacture, reduces the
33 capacitance between the base and control electrode
34 structures, and facilitates isolation of failed
35 emission sites from operation sites. It also can be

-4-

1 constructed by simple etching using standard
2 photolithography techniques.

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Brief Description of the Drawings

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A more detailed description of the invention in conjunction with a description of preferred particle emission structure incorporating the same, follows with reference to the accompanying drawings in which;

Fig.1 is an enlarged, broken perspective view illustrating a preferred particle field emission structure of the invention;

Fig.2 is a partial sectional view of the structure of Fig. 1, taken on a plane indicated by the lines 2-2 in Fig.1;

Fig. 3 is a schematic sectional view similar to Fig. 2 illustrating a potential field pattern established by the preferred embodiment of the invention, and the resulting trajectory of electrons emitted from the structure;

Fig. 4 is an enlarged, partial sectional view similar to Fig. 2 of a second preferred embodiment of the invention; and

Fig. 5 is another enlarged, partial sectional view of a third preferred embodiment of the invention.

Detailed Description

A field emission cathode array incorporating the invention is generally referred to in Figs. 1,2,

-5-

1 and 3 by the reference numeral 11. Cathodes of this
2 nature typically are associated with anodes which
3 attract the electrons emitted thereby. The cathode of
4 Figs. 1-3 includes an electrically conductive base
5 structure 12 from which electron emitting tips 13
6 project. While from the broad standpoint the emitting
7 tips could be separate from the base structure, it is
8 preferred and simpler to have the base structure and
9 the tips an integral structure.

10
11 The tips 13 are arranged on the base
12 structure to provide a plurality of spaced-apart
13 particle emission sites 14. Although only one tip is
14 illustrated at each emission site 14, it is within the
15 contemplation of the invention to have a multitude of
16 such tips at each of the sites. Moreover, base 12
17 structure provides both the necessary electrical
18 conduction for the tips and the structural support for
19 the same. It is recognized, though, that other
20 structure could be included to provide the structural
21 support. (For example, the base could be a thin film
22 or the like on a supporting substrate.) While the base
23 structure could be of a metal, it is preferred that it
24 be a semiconductor silicon wafer substrate of the type
25 used in the manufacture of integrated circuitry, doped
26 to a resistivity of the order of 0.01 ohm-cm. As will
27 become clearer from the description below relative to
28 Fig. 5, higher resistivities may be used in certain
29 circumstances to further enhance the beam shaping
30 effect of the field.

31
32 An electrically conductive control electrode
33 structure 16 is positioned to extract electrons from
34 the tips 13. In keeping with the invention, control
35 electrode structure 16 is made up of a plurality of

-6-

1 annular sections or rings 17, each of which
2 circumscribes an associated one of the emission sites,
3 connected together by linear sections 18. As
4 illustrated, the linear sections extend between
5 adjacent annular sections and provide electrical
6 conduction therebetween. Such control structure can be
7 of a metal compatible with the vacuum within which the
8 structure is located, such as, for example, molybdenum
9 or chromium.

10
11 The region between adjacent emission sites is
12 otherwise free of control electrode structure. The
13 result is that at such locations the structure does not
14 shield the spatial volume above the same, i.e., the
15 volume opposite that containing the base, from the
16 electric potential on the base.

17
18 Sandwiched between the base and control
19 electrode structures is insulating material 19.
20 Material 19 can be, for example, silicon dioxide
21 deposited on the substrate as a thin layer in the
22 ~~manner~~ ^{manner} discussed below. The control electrode
23 structure then simply can be a thin metal film of
24 molybdenum deposited on the layer of insulating
25 material 19. Both the layer of insulating material and
26 the film of metal then can be etched as discussed below
27 to assure that the regions between adjacent emission
28 sites are generally free of both. That is, in order to
29 achieve the desired field pattern with the structure
30 being described it is desirable that only the lead
31 connection sections with suitable insulation from the
32 base be provided in the regions between adjacent
33 emission sites to provide paths to conduct electrical
34 energy between the rings 17. The layer of insulating
35 material is removed by etching along with the metal

-7-

1 film between adjacent emission sites to reduce its
2 surface area to inhibit buildup of surface charge
3 which may interfere with establishing and maintaining
4 the desired potential field pattern.

5
6 A source of potential is represented at 21.
7 As illustrated, leads from the same extend to the base
8 structure 12 and control electrode structure 16 to
9 represent establishment of the potential difference
10 required to cause flow of negatively charged particles
11 from the sites 14 (reversing the applied potential will
12 produce positively charged particles).

13
14 As mentioned previously, with the geometrical
15 relationship illustrated between the base and electrode
16 structures, the potential on the base structure will
17 provide a desired potential field pattern above the
18 cathode tip structure to shape into generally parallel
19 beams, particles which emanate from the sites. This is
20 in addition to providing the potential required for
21 emission. Such field pattern, generally denoted by the
22 reference numeral 22 in Fig. 3, is represented in such
23 Fig. by equipotential lines 23. As shown, the pattern
24 is established by the potential on the base structure
25 except in those areas at which the control electrode
26 structure interferes with the same. Since such control
27 electrode structure is primarily made up of annular
28 sections 17 which circumscribe each of the emission
29 sites, the potential at the location of the emission
30 sites on the base will be shielded by the sections 17,
31 and the potential pattern above the cathode will have
32 "troughs" at the emission sites as illustrated. In the
33 arrangement being described, the lines 23 represent a
34 retarding field relative to the particles which are
35 extracted, with the result that the particles emanating

-8-

1 from each of the sites are turned toward a line
2 perpendicular to the control electrode surface. That
3 is, whereas in a conventional arrangement because the
4 control electrode structure extends generally
5 continuously between the emission sites a generally
6 uniform potential field pattern is established with
7 the result emitted electrons flare away from one
8 another due to angle of launch and mutual repulsion,
9 with the structure of the invention extracted electrons
10 are preferentially repelled by the field toward a line
11 parallel to the axes of the tips 13 to form the beams
12 24. The structure can be optimized to provide desired
13 shaping for a set emission level or angle of emission
14 by modelling the same to determine the best width of
15 the control electrodes for the given conditions.

16

17 It should be noted that while the linear
18 sections 18 of the control electrode will cause some
19 perturbations in the field pattern 22, these
20 perturbations can be made small enough to not
21 significantly affect the desired formation of the
22 beams 24.

23

24 While in general the simplest implementation
25 of the invention is in focusing emitted electrons into
26 parallel beams, different desired trajectories for
27 emitted particles can be achieved by different
28 geometries. Moreover, factors other than geometry
29 which affect the potential interaction between the
30 control and base electrodes can be varied. For
31 example, variations in the uniformity of the potential
32 difference, applied between the base and control
33 electrode structure, can be used to control the
34 trajectory of emitted particles.

35

-9-

1 The cathode 11 is quite simply constructed.
2 That is, layer of insulating material 19 is applied to
3 a base 12 and a continuous control electrode is formed
4 over the whole surface. Photo or electron lithography
5 is then used to pattern holes where tips are to be
6 formed by the process described in U. S. Patent Nos.
7 3,789,471 and 3,812,559. It is then a simple matter to
8 form the control electrode and the insulating material
9 into the desired geometry with conventional photoresist
10 and etchants via lithography techniques.

11
12 In those instances in which space charge
13 effects caused by exposed insulating material surfaces
14 in regions between emission sites is not a problem, it
15 is not necessary to etch or otherwise remove the
16 insulating material from the base structure. Fig. 4 is
17 included simply to illustrate the structure which
18 results when the insulating material is not removed.
19 The embodiment of such figure is in all other respects
20 the same as that described earlier, and the same
21 reference numerals are used to identify the parts.

22
23 As mentioned previously, the effects of the
24 invention can be achieved by appropriately varying
25 potential differences between the control and base
26 electrodes at difference spatial locations. Fig. 5
27 illustrates an embodiment of the invention at which
28 such distribution of potential differences is
29 achieved. The embodiment of the invention of Fig. 5
30 takes advantage both of this distribution of potential
31 difference and the geometrical relationship of the
32 earlier described embodiments without the necessity of
33 requiring different potentials to be applied either to
34 the base or to the control structures. It also
35 provides an enhanced influence of the base field on the

-10-

1 trajectory of emitted electrons. With reference to
2 such figure, the base structure, referred to by the
3 reference numeral 12', is a semiconductive material
4 which is doped to, in essence, become conductive with
5 high resistivity. It could be, for example, silicon
6 which is doped with a conductive material to be a P
7 type material having a resistivity of 500 ohm-cm. A
8 continuous, conductive base plane 26 is also included
9 to enable a desired potential to be applied to the base
10 throughout its surface area opposite that from which
11 the tips 13' are formed.

12
13 This embodiment is otherwise similar to the
14 previously described embodiments and primed reference
15 numerals are used to identify corresponding parts.

16
17 When current is drawn from the emitter tips
18 13' there will be a voltage gradient established in the
19 base 12' that is determined by the resistance
20 associated with the base silicon and the amount of
21 current drawn from such emitter tips. The
22 electrostatic field in the volume above the control
23 electrodes is thereby enhanced, because the potential
24 of the surface of the silicon between the emitter tips
25 is more negative than the surface of the silicon
26 directly under the tips. This effect is an automatic
27 consequence of the current drawn through the silicon
28 base as a result of the emission process. It is as
29 though there is a resistor in series with each emitter
30 tip that causes each tip to become more electrically
31 positive as the emission from that tip is increased.
32 The resistance of the base structure between the tips
33 remains essentially the same, with the result that we
34 have a distributed resistance in the base and there
35 will be a radial field gradient emanating from the base

-11-

1 of each tip as shown in Fig. 5. This field is the
2 direct consequence of the emission current flowing
3 through the silicon base and increases automatically
4 with increased emission. The imaginary resistor for
5 each emitter tip is represented in the figure at 27.

6
7 It is to be noted that the equipotential
8 lines penetrate the base 12'. Moreover, the series
9 resistance at each of the tips has the acts as a
10 buffering resistance that protects each emitter tip 13
11 from experiencing a damaging over-current burst in the
12 event of a sudden change in surface condition of the
13 tip due to desorption of surface contaminants or the
14 like.

15
16 It should be noted that the resistivity of
17 the silicon base can be designed to optimize the
18 trajectories for a given emission level, and that the
19 effect is somewhat self compensating in that increased
20 emission tends to produce increased angular spread;
21 however, increased emission also causes the exposed
22 silicon base between tips to be more negative than the
23 tips, thereby increasing the strength of the fields
24 that are tending to straighten the particle
25 trajectories.

26
27 It will be appreciated from the above that
28 the invention provides automatic focusing without the
29 necessity of additional focusing structure. It does so
30 simply by controlling the interaction between the base
31 and control electrodes responsible for the emission of
32 particles. Thus, the invention represents a
33 significant advance in the field emission cathode art.
34 While it has been described in detail in connection
35 with preferred embodiments thereof, those skilled in

-12-

1 the art will recognize that various changes and
2 modifications can be made without departing from its
3 spirit. It is therefore intended that the coverage
4 afforded applicant be defined by the following claims.
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CLAIMS

I Claim:

1 1. A particle field emission structure
2 comprising, in combination: at least one particle
3 emission site having one or more emitting tips for
4 electrically charged particles; an electrically
5 conductive base structure positioned to provide
6 electrical energy to said emitting tips for
7 electrically charged particles to be emitted
8 therefrom; an electrically conductive control electrode
9 structure positioned at said site for controlling the
10 extraction of particles from said site; said control
11 electrode and base structure being selected to have an
12 electromagnetic interaction establishing a potential
13 field pattern in the spatial volume adjacent said
14 control electrode structure opposite said base
15 structure which will provide desired trajectories
16 therethrough of particles formed at said site when a
17 potential difference is established between said base
18 structure and said control electrode to extract
19 electrically charged particles from the site.

1 2. The particle field emission structure of
2 claim 1 wherein said electrically conductive base
3 structure is integral with said emission site, and said
4 one or more electrically charged particle emitting
5 tips project from said base structure.

-14-

1 3. The particle field emission structure of
2 claim 1 wherein said tips are electron emitting tips
3 and said particles to be extracted therefrom are
4 electrons.

1 4. The particle field emission structure of
2 claim 1 wherein said potential difference between said
3 base structure and control electrode is varied relative
4 to the spatial location of said electrodes to one
5 another.

1 5. The particle field emission structure of
2 claim 1 wherein there are a plurality of said particle
3 emission sites spaced apart from one another and said
4 control electrode and base structures have geometrical
5 shapes between said sites which are related to one
6 another so as to establish said potential field
7 pattern.

1 6. The particle field emission structure of
2 claim 5 wherein said potential difference between said
3 base structure and control electrode is varied relative
4 to the spatial location of said electrodes to one
5 another.

1 7. The particle field emission structure of
2 claim 5 wherein said geometrical shapes are selected to
3 have a relationship to direct particles emitted from
4 said sites into said volume, into generally
5 non-diverging beams.

-15-

1 8. The particle field emission structure of
2 claim 6 wherein said electrically conductive base has a
3 generally continuous and planar surface between said
4 emission sites and the electrode structure includes
5 generally annular sections for said sites, each of
6 which circumscribes an associated one of said sites,
7 and a generally linear conduction sections extending
8 between adjacent annular sections, the region between
9 adjacent emission sites otherwise being free of control
10 electrode structure whereby potential on said control
11 structure generally does not interfere with potential
12 on said base defining said potential field pattern in
13 said region.

1 9. The particle field emission structure of
2 any of the previous claims, further including an
3 electrical insulator structure at each of said sites
4 between said electrically conductive base and said
5 control electrode structure.

-16-

1 10. A method of generating electrically
2 charged particles and controlling the initial
3 trajectory thereof, comprising the steps of:

4 A. Providing at least one particle emission
5 site having one or more electrically charged particle
6 emitting tips;

7 B. Providing an electrically conductive
8 base structure positioned to provide electrical energy
9 to said emitting tips for electrically charged
10 particles to be emitted therefrom;

11 C. Providing an electrically conductive
12 control electrode structure at said site for
13 controlling the extraction of particles from the
14 emitting tips thereat; and

15 D. Controlling the potential field pattern
16 which will interact with electrically charged
17 particles in the spatial volume adjacent said control
18 electrode structure opposite said base by selecting a
19 desired electromagnetic interaction between said base
20 and control electrode structures during the extraction
21 of particles from said site.

1 11. The method of claim 10 wherein said step
2 of controlling the potential field pattern which will
3 interact with charged particles produced at each of
4 said sites includes providing a preselected geometrical
5 relationship between said base structure and said
6 control electrode structure adjacent said site.

-17-

1 12. The method of claim 11 wherein said step
2 of controlling the potential field pattern which will
3 interact with charged particles produced at each of
4 said sites includes distributing the potential
5 differences between said base structure and said
6 control electrode structure.

1 13. The method of claim 10 wherein said
2 steps of providing at least one charged particle
3 emission site and providing an electrically conductive
4 base structure comprises the step of providing an
5 electrically conductive base structure having one or
6 more electrically charged particle emission tips
7 extending integrally therefrom to define said emission
8 site.

1 14. The method of claim 13 wherein said step
2 of providing a base structure includes providing an
3 electrically conductive base structure defining a
4 plurality of spaced-apart charged particle emission
5 sites, each of which includes one or more of said
6 emitting tips integral with said base structure;
7 wherein said step of providing a control electrode
8 structure at said site includes providing such a
9 structure for each of said sites; and said step of
10 controlling the potential field pattern in said
11 spatial volume includes selecting a desired
12 electromagnetic interaction between said base and
13 control electrode structure at and adjacent said
14 plurality of sites during the extraction of particles
15 from the same.

-18-

1 15. The method of claim 14 wherein said step
2 of providing an electrically conductive control
3 electrode structure for each of said sites includes
4 providing a common control electrode for said sites
5 having generally annular sections, each of which
6 circumscribes an associated one of said sites, and
7 generally linear connection sections providing
8 conductive paths connecting said plurality of annular
9 sections.

1 16. The method of claim 14 wherein said step
2 of controlling the potential field pattern which will
3 interact with electrically charged particles produced
4 at each of said sites includes maintaining said base
5 substantially free of shielding by said control
6 electrode structure in the regions between said
7 spaced-apart sites.

1 17. The method of any of the previous claims
2 10 through 16 wherein each of said spaced-apart
3 particle emission sites are electron emission sites.

-19-

- 1 18. A method of constructing a particle
2 field emission structure which comprises the steps of:
3 A. Forming a plurality of spaced-apart,
4 electrically charged particle emission sites on one
5 surface of a base structure;
6 B. Applying insulating material on said
7 surface with first apertures therethrough located at an
8 associated one of said particle sites;
9 C. Applying a generally continuous and
10 planar layer of electrically conductive material on
11 said insulating material with second apertures
12 therethrough, each of which registers with an
13 associated one of said first apertures; and thereafter
14 D. Removing substantially all of said layer
15 of electrically conductive material between said sites.

- 1 19. The method of claim 18 of constructing a
2 field emission cathode wherein said step of removing
3 includes leaving between said sites, lead sections of
4 said electrically conductive material to provide the
5 electrically conductive paths necessary for common
6 energization of a plurality of said sites.

- 1 20. The method of claim 18 wherein said step
2 of removing substantially all of said layer of
3 electrically conductive material includes etching said
4 material from said insulating material in a
5 preselected pattern.

-20-

1 21. The method of claim 18 wherein said
2 insulating material is applied as a layer on said
3 surface of said base structure, and further including
4 the step of removing substantially all of said layer of
5 insulating material between said particle emission
6 sites.

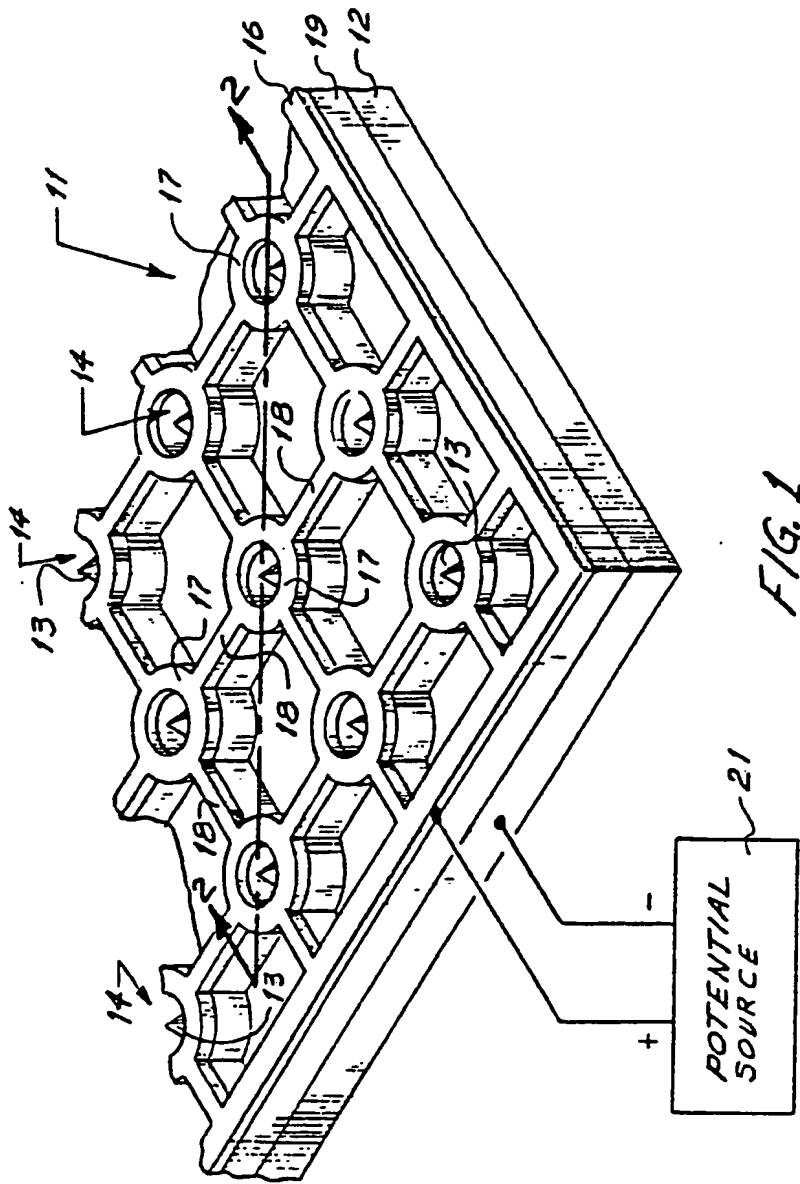


FIG. 1

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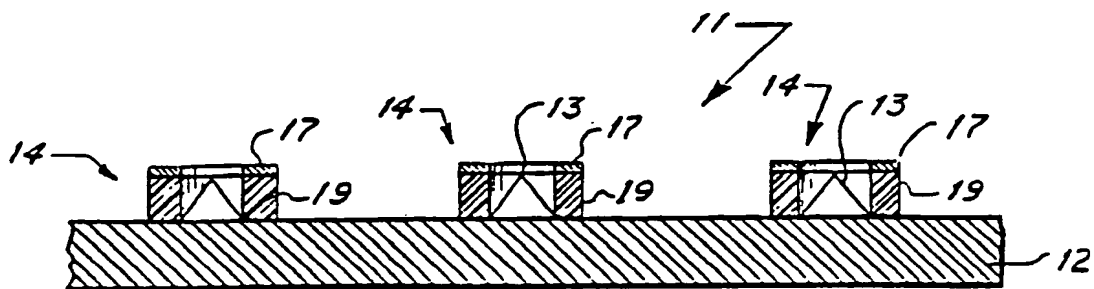


FIG. 2

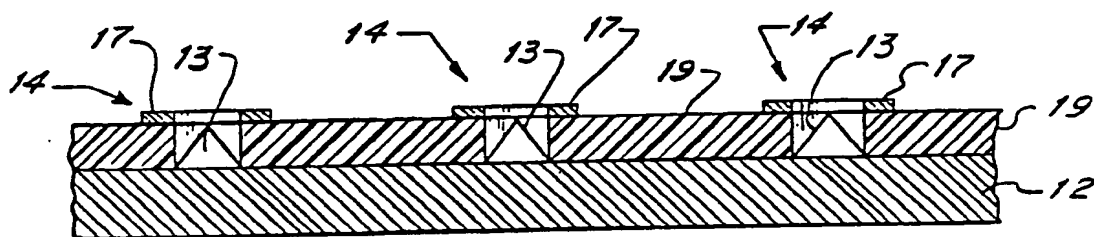


FIG. 4

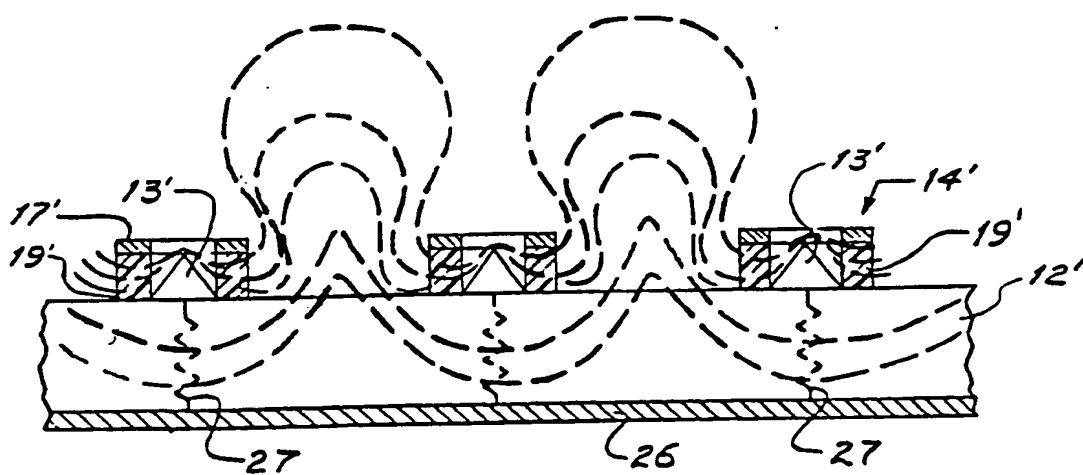
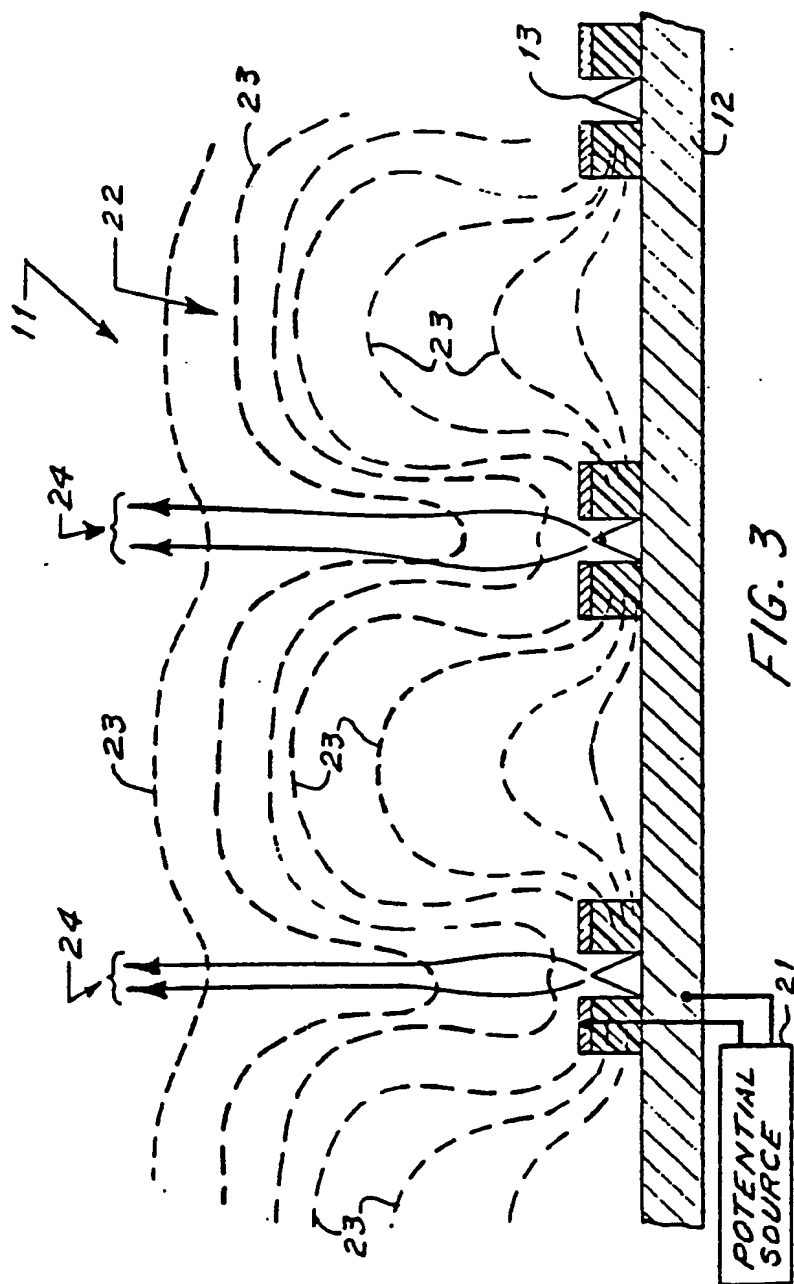


FIG. 5



INTERNATIONAL SEARCH REPORT

International Application No. **PCT/US 89/01982**

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC ⁴ : H 01 J 1/30, H 01 J 9/02		
II. FIELDS SEARCHED		
Minimum Documentation Searched ⁷		
Classification System	Classification Symbols	
IPC ⁴	H 01 J	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched ⁸		
III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹		
Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A	US, A, 3753022 (D.L. FRASER, Jr) 14 August 1973, see column 2, lines 42-53; figure 1 --	1,10,18
A	US, A, 4498952 (A.O. CHRISTENSEN) 12 February 1985, see abstract; figures 14-17 cited in the application --	1,10,18
A	US, A, 3453478 (K.R. SHOULDERS et al.) 1 July 1969, see column 2, lines 65-68; figures 1,2 --	1,10,18
A	Patent Abstracts of Japan, vol. 7, no. 36 (E-158)(1181), 15 February 1983 & JP, A, 57187849 (NIPPON DENSKIN DENWA KOSHA) 18 November 1982 --	1
A	EP, A, 0184868, (PHILIPS) 18 June 1986 ----	
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IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
23rd August 1989	15 SEP 1989	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	T.K. WILLIS	

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

US 8901982

SA 28827

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 08/09/89. The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 3753022	14-08-73	None	
US-A- 4498952	12-02-85	None	
US-A- 3453478	01-07-69	US-A- 3497929	03-03-70
EP-A- 0184868	18-06-86	NL-A- 8403613	16-06-86
		CA-A- 1249012	17-01-89
		JP-A- 61131331	19-06-86
		US-A- 4682074	21-07-87

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